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# Tools for identifying Australian aquatic oligochaetes of the families Phreodrilidae, Lumbriculidae and Capilloventridae (Clitellata: Annelida)

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## Abstract

Keys are provided to three families of aquatic Oligochaeta: Phreodrilidae, Lumbriculidae and Capilloventridae. There are currently 32 described phreodrilids known from Australia, out of 54 described worldwide, but there are at least 17 more undescribed. Three of the five described capilloventrids are known only from south-eastern Australia. There are only two species of Lumbriculidae in Australia, both of which are believed to be recent introductions.

## Keywords

Aquatic oligochaetes, Annelida, Clitellata, identification, Australia, Phreodrilidae, Capilloventridae, Lumbriculidae

## Introduction

There have been significant changes in oligochaete systematics and gains in knowledge of Australian oligochaete[1] diversity in the two decades since Pinder and Brinkhurst (1994) produced their guide to identifying Australian freshwater oligochaetes. Pinder (2010) summarised these changes and provided new keys to families of oligochaetes occurring in Australia and to species of non-tubificoid Naididae (former Naididae *sensu strictu*). This guide extends Pinder (2010) by providing keys to the Phreodrilidae, Capilloventridae and Lumbriculidae.

Phreodrilidae is primarily a southern hemisphere family, with most species known from Australia, a few in Africa or New Zealand, two in South America, one in Sri Lanka and others on southern oceanic islands. However, immature (and therefore unidentifiable) phreodrilids have been collected in Ireland (Gunn et al., 2003) and the Thames River at London (Pinder et al. in press) and one species is known only from Japan (Martin and Ohtaka, 2008). Almost all of the Australian phreodrilids are endemic and most are known from very few localities and appear to be geographically restricted. Most species are known only from Tasmania or Western Australia. There are currently 32 described species known from Australia (Erséus and Pinder, 2003; Pinder and Brinkhurst 1997, Pinder 2003 and Pinder, 2008) out of 54 described worldwide. Only three of the species occurring in Australia also occur elsewhere but I suspect that Australian populations of at least two of these represent endemic species. There are at least 17 additional species known but undescribed in Australia and it is likely that at least as many await discovery.

Phreodrilids are primarily freshwater worms, but *Astacopsidrilus ostiensis* Pinder and Erséus, 2003 is an estuarine species from Tasmania. While most species are known from streams, rivers and wetlands, several in Australia, New Zealand, North Africa and the Middle East, occur in groundwater, with some Australian species occurring in both epigean and subterranean waters. A few species of *Astacopsidrilus* are ectocommensal on crayfish, but the majority are free-living. All seem to be detritivores. The two *Schizodrilus* (both New Zealand endemics) occur in forest leaf litter.

Capilloventridae (and the only genus, *Capilloventer*) was established by Harman and Loden (1984) for *Capilloventer atlanticus*, a marine species from Brazil. Two other species, *Capilloventer australis* from the estuary of the Hawkesbury River and *Capilloventer antarcticus* from the subantarctic Weddell Sea were described by Erséus (1993). Two further species (*Capilloventer longicapitus* and *Capilloventer acheronensis*) from Victorian streams were described by Pinder and Brinkhurst (1997b). Pinder and Brinkhurst (1997b) also thought they had an immature capilloventrid from south-western Australia but this is yet to be confirmed (it may have been an aeolosomatid polychaete). Very little is known about capilloventrids.

There are only two species of Lumbriculidae in Australia, both of which are believed to be recent introductions. *Lumbriculus variegatus* (or one or more of its cryptic forms) primarily occurs in catchments associated with human population centres and has probably been introduced and spread by aquarists or aquaculture. It appears to have recently colonised the glacial lakes of Kosciusko (Brian Timms pers. comm.[2] ), perhaps at the expense of the endemic phreodrilid *Phreodriloides notabilis*. *Stylodrilus heringianus* has only been recorded in Tasmania's Lake Sorell (Fulton 1983) within Australia but there are records from New Zealand.

Information on the classification and diversity of Australian aquatic oligochaetes is provided in Pinder (2010). All illustrations are by the author unless otherwise acknowledged.

[1] Following recognition that leeches and some other annelids that produce cocoons via clitella are derived from oligochaete ancestors (Martin 2001; Erseus and Kallersjo 2004) the names Oligochaeta and Clitellata became synonymous, with the latter name generally taking preference. Nonetheless, aquatic earthworms are still informally referred to as oligochaetes.

[2] Brian Timms. University of New South Wales. December 2012 by email. Identifications confirmed by author.

This work was originally produced for a workshop associated with the 12th International Symposium on Aquatic Oligochaeta in Fremantle, September 2012.

## Characters

Pinder (2010) provided a general overview of morphology in oligochaetes, so this section will focus on those characters most useful for identifying phreodrilids, lumbriculids and capilloventrids.

***Arrangement of the body***

Roman numerals are used to denote segments (Figure 1) while Arabic numerals are used to denote septa (walls) between segments (1/2, 2/3 …). The head end is usually broader than the tail end of a worm. The most anterior part of the worm is the prostomium which is not counted as a segment (Figures 1 and 2). This is followed by segment I which has the crescent-shaped ventral mouth but no chaetae. Chaetae generally start on segment II but dorsal (and rarely ventral) chaetae may be absent on some anterior segments.

A useful orienting feature is the nerve cord which is normally easy to see on slide mounted worms and is always mid-ventral (Figures 1 and 2). The nerve cord is uneven in width and has a granular appearance. The mouth is also ventral and long hairs (see below) are normally only present dorsally.

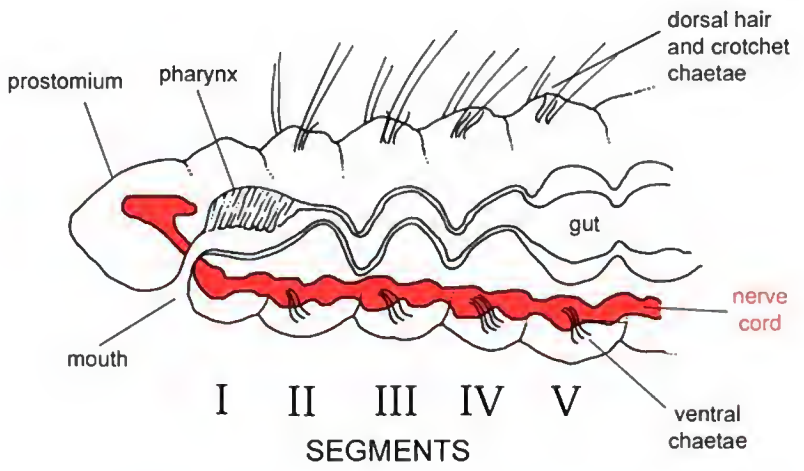


Figure 1. Major features of the anterior end of an oligochaete.

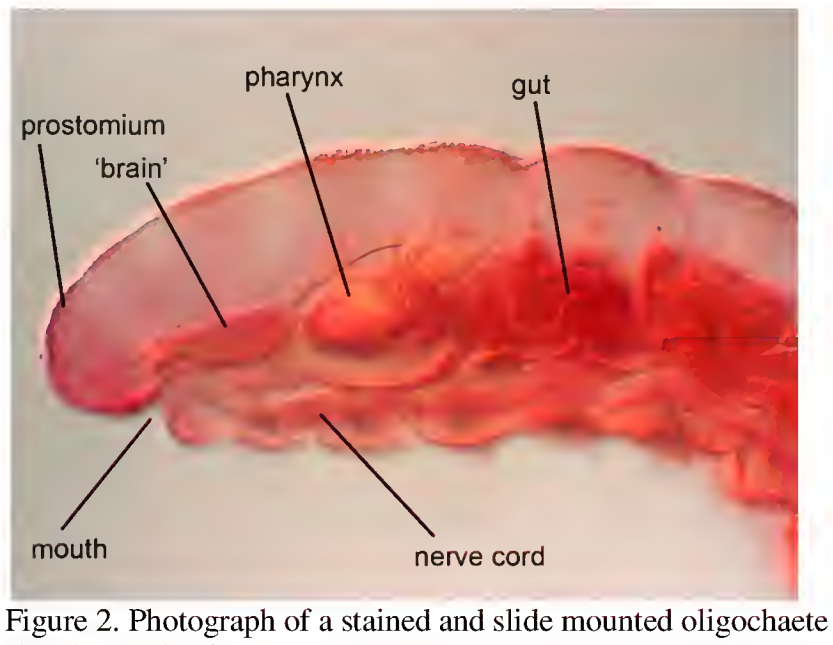


Figure 2. Photograph of a stained and slide mounted oligochaete showing major features.

***Body size*** Some worms are always very small (< 5 mm) while others are generally larger when mature (e.g. > 20 mm) but body size varies within species so is not always useful.

***Proboscis*** Two species of the phreodrilid genus *Antarctodrilus* have a narrow extension (proboscis) on their prostomium (Figure 3). *Capilloventer longicapitus* has an elongated prostomium (Figure 45).


Figure 3. Anterior segments of *Antarctodrilus proboscidea*.

***Gills*** A few oligochaetes have gills. *Dero* (Naididae) have gills in a chamber on the last segment. Three species have gills along their body: *Branchiura sowerbyi* (Naididae: Rhyacodrilinae), *Branchiodrilus hortensis* (Naididae: Naidinae) and *Phreodrilus branchiatus* (Phreodrilidae) (Figure 35).

***Chaetae*** (= setae of some authors). Chaetae occur in groups called bundles (although sometimes there will only be one chaeta per 'bundle'). Most oligochaetes have 4 bundles per segment (2 ventro-lateral and 2 lateral to dorso-lateral). Chaetae are absent on the prostomium (head) and segment I but present on all or most segments thereafter, except for the anal segment (pygidium) and sometimes on segments with the genital pores. There are several main kinds of chaetae as follows.

***Hair chaetae*** (sometimes just called hairs or capilliform chaetae): Long, thin chaetae, normally with a fine tapering tip. In most oligochaetes (except for capilloventrids and 2 undescribed naidids) these are restricted to dorsal bundles. Hairs sometimes have annulations or serrations along the shaft (Figure 36) or have shafts or tips that appear frayed or plumose (Figure 14).

***Crotchet chaetae*** (Figure 4): Non-hair chaetae, usually sigmoid in shape, usually with a swelling (nodulus) along the shaft, with tips either single-pointed (=simple) (a bluntly or sharply pointed tip), bifid (forked), pectinate (with comb-like teeth between the fork) or otherwise modified (e.g. paddle-shaped). In bifid and pectinate chaetae the 'upper' tooth is the one on the convex side of the chaeta and the 'lower' tooth is on the concave side, though sometimes curvature is difficult to detect. The relative length of the teeth is frequently used in keys and is measured as a straight line from where the teeth meet to the tips.

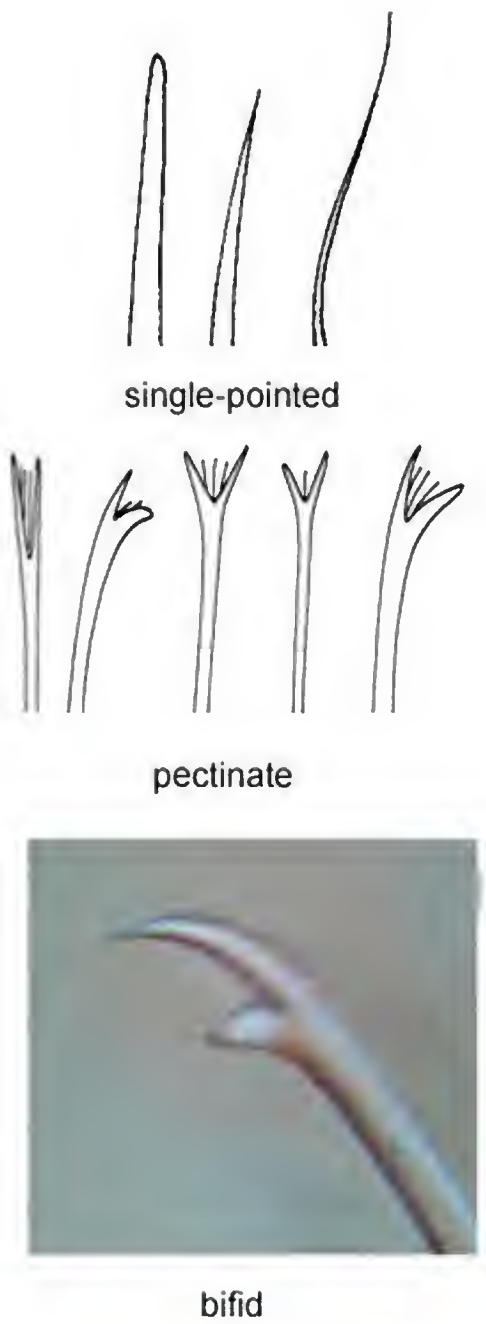


Figure 4. Tips of crotchet chaetae.

***Genital chaetae*** The ventral chaetae of mature specimens are usually lost or modified on the segments bearing the genital pores. Modified chaetae are mostly of two forms, 1) long straight single chaetae with hollow distal halves and sharp blade-like tips, associated with a large gland and often associated with one much smaller chaeta (Figure 5, left) and 2) one or more chaetae, often in parallel or with the distal ends bunched together, with bifid or simple tips. The former type are most closely associated with spermathecal pores and then called spermathecal chaetae, whereas the latter are usually associated with the male pores and then known as penial chaetae. Both types are largely hidden within the body but can be seen in stained and cleared specimens. Genital chaetae of capilloventrids are long thickened hairs (Figure 6 and Figure 9).

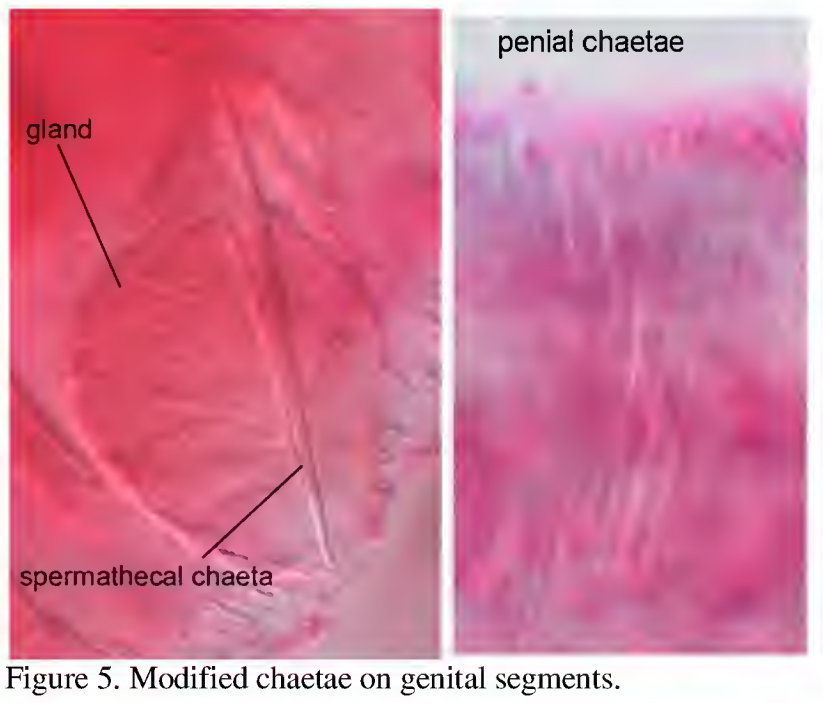


Figure 5. Modified chaetae on genital segments.

***Phreodrilid chaetae*** Ventral chaetae on phreodrilids are always present from segment II onwards, other than an absence on segments XII (and often XIII) on mature specimens. There are usually 2 per ventral bundle, though very rarely there will be a duplication to give 4 in one or a few bundles. Ventral chaetae are always of the crotchet type, with tips that are either single-pointed or bifid (forked, usually with the upper tooth much smaller than the lower) or the bundles will have one of each (Figures 11 and 12). Normally, the form of the ventral chaetae only changes slightly from anterior to posterior.

Phreodrilid dorsal chaetae are absent in segment II but normally present from III. In a few species, dorsal chaetae are absent in a few other anterior segments. There are normally one to a few hairs per bundle, though a few species have crotchet chaetae rather than hairs dorsally. Dorsal chaetae normally each have a pair of small 'support chaetae' at their base that do not protrude from the body (Figure 13). The number and form of the dorsal chaetae can change along the body. The number of chaetae per bundle generally decreases posteriorly, though in some species it increases, especially near the tail and sometimes dramatically so. A few species have hairs with annulated shafts (Figure 36) or plumose tips (Figure 14).

Species with ventral spermathecal pores on XIII (see below) usually have modified ventral chaetae on that segment (rarely also on XII). These 'spermathecal chaetae' (Figure 5, left) are usually paired, with one much longer and with a hollow ectal portion and one much smaller (not always visible) and apparently solid. These are embedded within an ovoid gland (the smaller one often entirely so) and either protrude into an invagination of the body wall (spermathecal vestibule) around the spermathecal pore or have their own opening on the body wall.

***Capilloventrid chaetae*** Dorsal and ventral chaetae are absent in II and usually absent in III and are normally similar in form. The chaetae of each side are located close together (i.e. more lateral than dorso- or ventro-lateral) and consist of combinations of hairs or single-pointed or bifid crotchets or both. In some bifid chaetae there is a subdental ligament, connecting the end of the lower tooth to the shaft (Figure 6). The ventral chaetae of XII are modified into long broad hair-like 'penial chaetae' (Figures 6 and 9, pc).

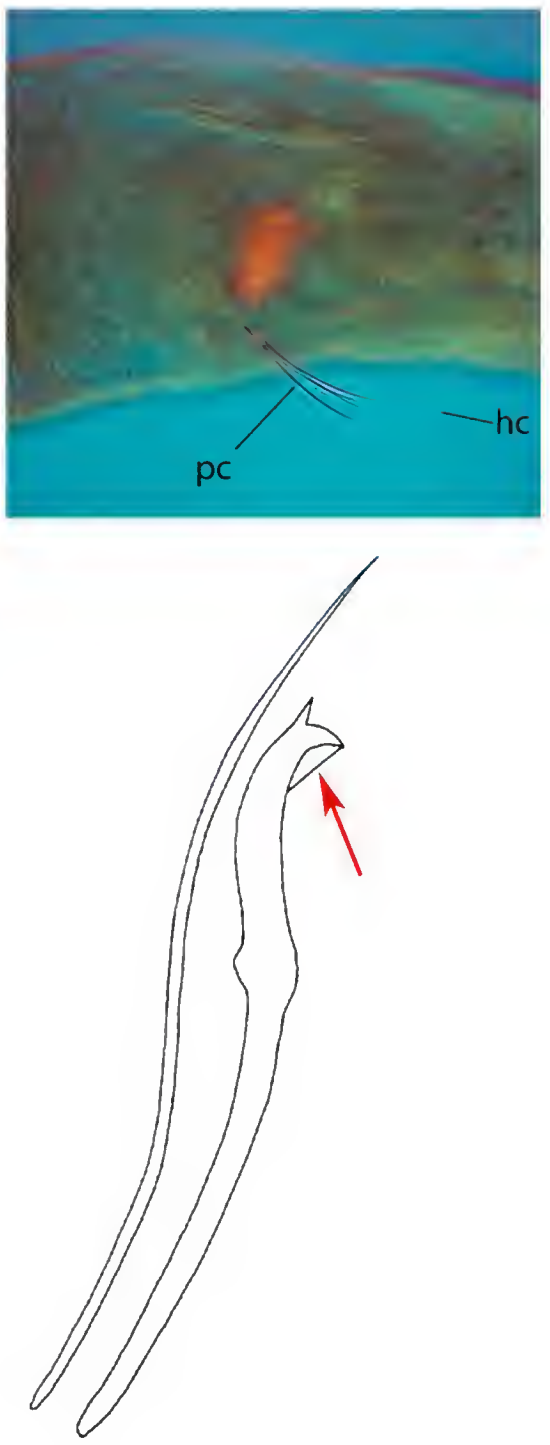


Figure 6. *Capilloventer australis* chaetae. Top: modified penial chaetae (multiple broad hairs, pc) and a normal hair chaeta (hc). Bottom: Posterior chaetae (crotchet and hair) of with subdental ligament indicated by arrow (from Pinder and Brinkhurst 1997b, © John Wiley & Sons Pty Ltd).

***Lumbriculid chaetae*** All lumbriculid chaetae are crotchets (i.e. no hairs). They are usually single-pointed but are bifid (with very small upper teeth) in the two species known from Australia. Chaetae on the genital segments are not modified.

***Genitalia*** External features such as the chaetae, gills and proboscis can get you only so far when identifying oligochaetes. Identification to family is usually possible just from external features (including position of the clitellum and genital pores) and the keys below and in Pinder (2010) will allow identification of some species from external features alone. However, for many species, examination of internal features (usually just the genitalia) will be required. Moreover, confirmation of an identification arrived at by using a key should be confirmed by examination of the genitalia where possible.

Examination of the genitalia requires a sexually mature worm and the easiest way to determine whether a worm is mature is to look for the clitellum. This is two or more segments with thickened and more opaque body wall and with a different texture resulting from development of a glandular layer of cells (Figure 7). The location of the clitellum differs between families (Table 1).

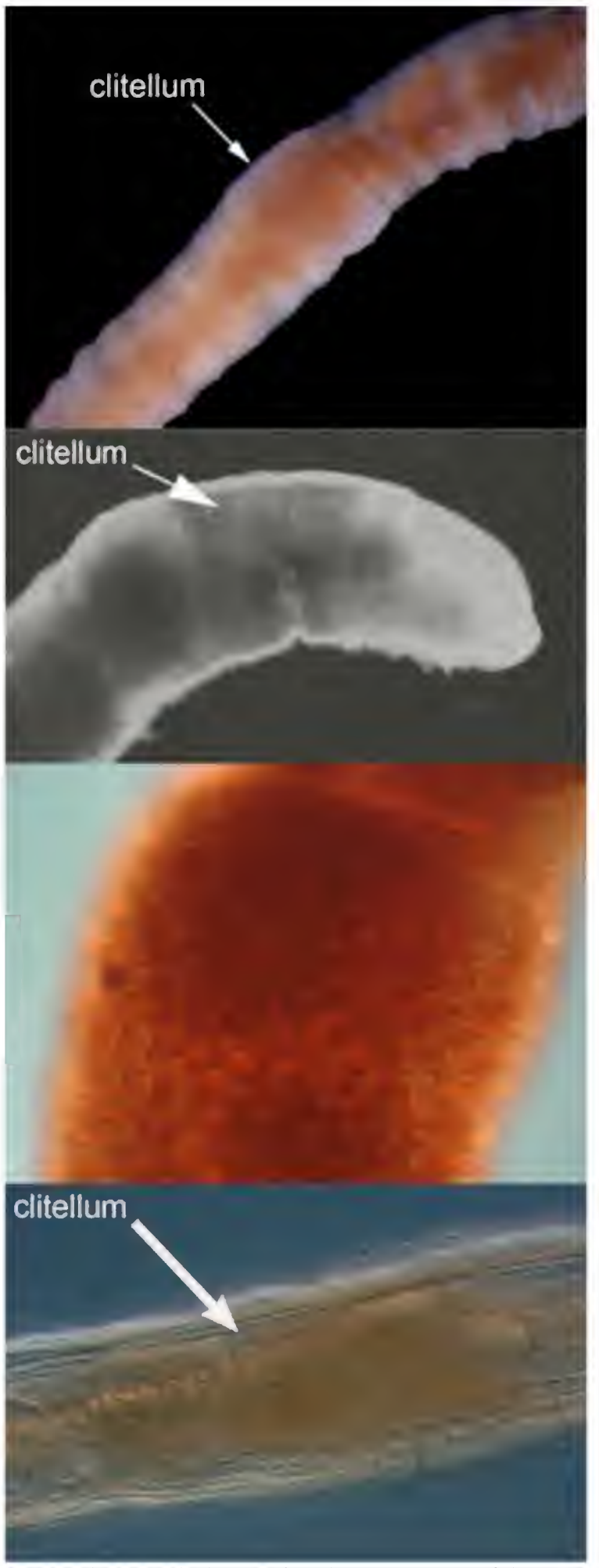


Figure 7. Photographs illustrating the appearance of the clitellum on a variety of oligochaetes.

Table 1. Location of clitellum on oligochaete families.

| **Taxon** | **Clitellum location** |
|---|---|
| Naididae (Naidinae) | two consecutive segments between IV and VIII |
| Naididae (other subfamilies) | X and XI |
| Enchytraeidae | XI and XII |
| Phreodrilidae | ½ XII and all of XIII |
| Lumbriculidae | several segments from VIII or IX |
| Capilloventridae | ½ XII to XIV |
| Haplotaxidae | over several segments from about X or XI |

**Worm sex.** Oligochaetes are hermaphrodites so have male and female genitalia arranged in pairs on each side of the body. During copulation sperm is swapped between two worms, with sperm transferred from the male pore of one worm to a different pore on its mate that leads to a sperm storage organ called a spermatheca. After the worms separate the clitellum secretes a cocoon, into which is deposited the egg(s) from the female pore and the stored sperm from the spermaethecal pore. The cocoon is then shed like a sleeve and the embryo develops in the cocoon (Figure 8).

Figure 8. An aquatic oligochaete cocoon with two embryos.

Oligochaete genitalia consists of the following elements.

The paired testes and ovaries are usually located in two adjacent segments, usually in or near the segments bearing the clitellum. There is usually one pair of each, but in haplotaxids and lumbriculids there may be more than one pair.

The male ducts transport sperm from the testes to the male pore. The normally paired ducts start with male (=sperm) funnels on the posterior wall of the segment containing the testes and in mature stained specimens this can be seen as a red mass of cilia looking like a dense tassel. The funnel feeds sperm into the vas deferens which leads to the male pore, usually via an atrium with associated glands (prostate) and a penis lying in an invagination of the body wall (penis sac), but there are many variations on this template. The pores are usually on the ventro-lateral body wall of the post-testes segment (=ovarian segment) but in lumbriculids and earthworms pores can be 2 or more segments behind the testes.

The female genitalia is much simpler, consisting of a pair of ovaries (usually in the segment with the male pores) and short female ducts carrying eggs to a pore located anteriorly on the next segment.

The spermathecae are paired sacs (also known as spermathecal ampullae) connected to the exterior via ducts leading to pores which sometimes lie within an invagination of the body wall (spermathecal vestibulae).

**Capilloventrid genitalia** (Figure 9). Capilloventrids have testes in XI and ovaries in XII or XIII and spermathecae in VII (the latter with lateral pores on the same segment). The male funnels on the posterior septa of XI lead directly to ventral pores on segment XII (i.e. no atria, prostate or penis). Chaetae of segment XII are modified as long broad hairs.

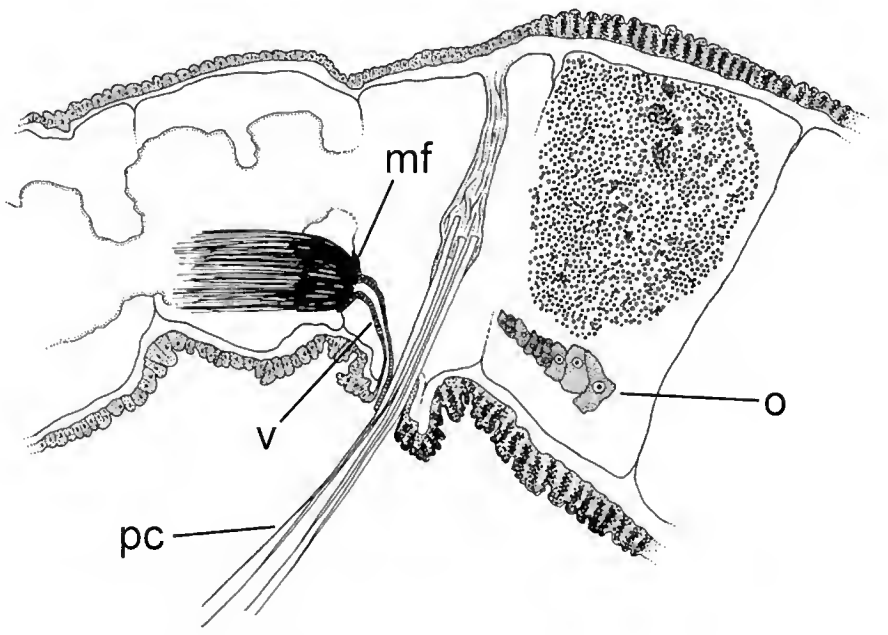


Figure 9. Genitalia of *Capilloventer australis*. mf = male duct, o = ovary, pc = penial chaetae, v = vas deferens. From Pinder and Brinkhurst (1997b), © John Wiley & Sons Pty Ltd.

***Lumbriculid genitalia*** While most oligochaete families have a pair of testes in one segment followed by a pair of ovaries and male pores in the next segment, lumbriculids have more complex and variable genitalia. Usually, there are two or three pairs of testes, ovaries and male ducts. The male ducts occur in segments bearing the testes rather than in the subsequent segment and in some species two pairs of testes (in adjacent segments) produce sperm for a single set of male ducts. Fortunately in Australia we don't have to deal with this diversity as there are only two species, and these can be distinguished without reference to internal genitalia, and one of these species mostly reproduces asexually anyway.

***Phreodrilid genitalia*** (Figure 10). Phreodrilids have testes in XI, male ducts (vas deferentia, atria and penes) and ovaries in XII and spermaethecal pores in XIII connected to ampullae in one or more segments from XIV. In most phreodrilids the atrium is a solid gland with a narrow lumen but in some species the lumen is expanded and all or part of the atrium is used for storing sperm prior to mating. In the genus *Phreodrilus*, the atrium has become modified into an 'eversible pseudopenis' (Figure 10, top) through separation of the outer (muscle) and inner (epithelial) layers, with the inner layer forming a loose tube within the muscular sac. In some species this inner layer has become very long and forms a coiled tube. The inner layer can be everted during copulation so acts as a penis. In most other phreodrilids the male pore terminates on a 'pendant penis' formed by a double folding of the body wall (Figure 10, bottom) which can be protruded. The size and shape of the atrium and penes vary greatly between species. There are no prostate glands, as in many Naididae, because the glandular atrium plays that role.

Spermathecal pores are usually located within vestibulae (shallow to deep invaginations of the body wall) which open to the exterior either ventro-laterally or dorso-laterally. In the genus *Nesodrilus* there are no vestibulae and the spermathecal pores are ventral. The vestibulae vary greatly in size and musculature. The narrow spermathecal ducts open out into the ampullae which extend over one or more segments from XIV. In some species with ventral spermathecal pores the ventral chaetae are modified as 'spermathecal chaetae' on segment XIII (Figures 5, 31 and 33).

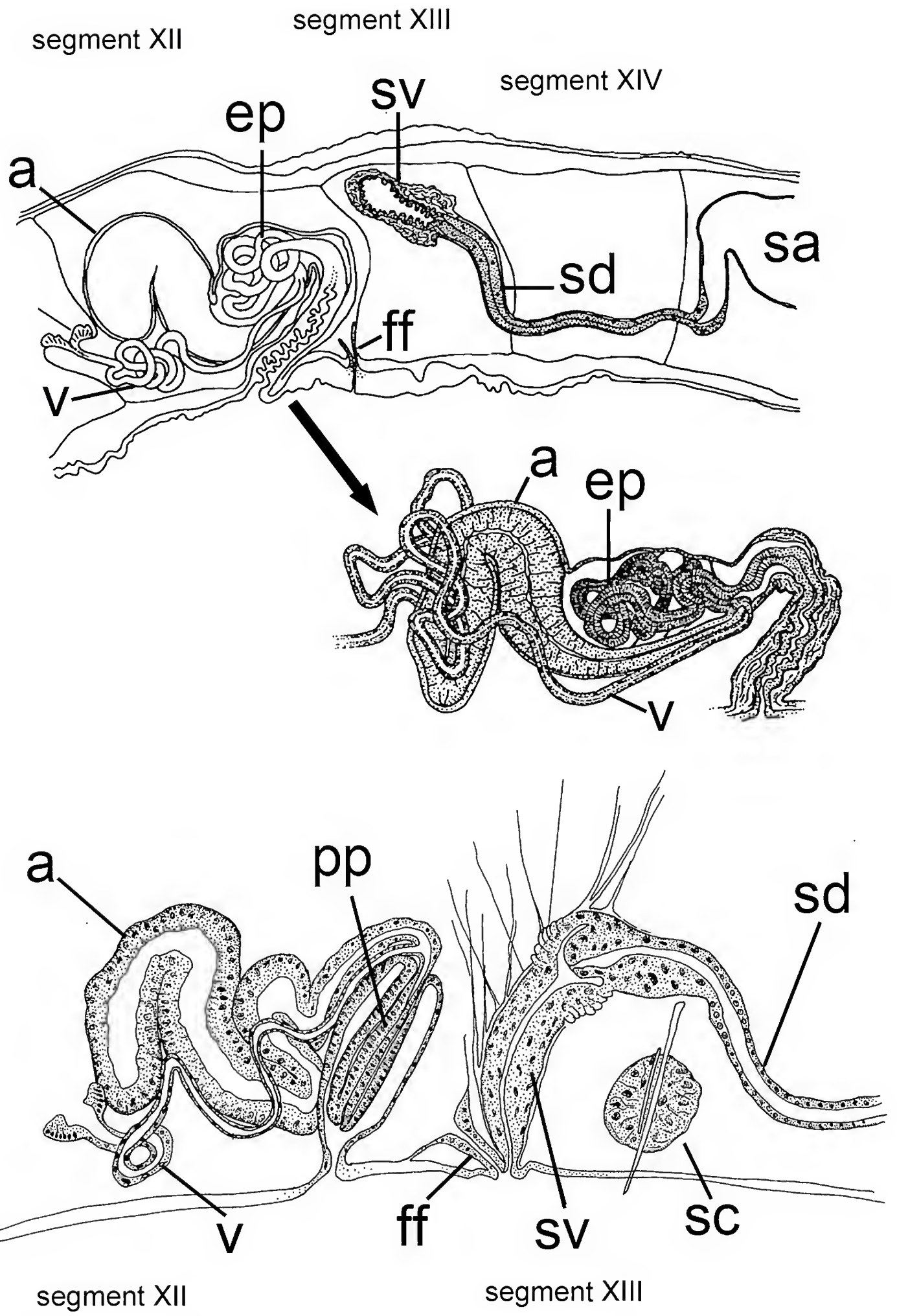


Figure 10. Genitalia of Phreodrilidae: *Phreodrilus diemenensis* (top) and *Insulodrilus angela* (bottom). a = atrium, ff = female funnel, ep = eversible pseudopenes, pp = pendant penis, sa = spermathecal ampulla, sc = spermathecal chaetae, sd = spermathecal duct, sv = spermathecal vestibule, v = vas deferens. From Pinder and Brinkhurst (1997a) and Pinder (2003), © CSIRO Publishing and Western Australian Museum respectively.

## Key to Australian Phreodrilidae

This key will allow a label to be put on specimens, but full species descriptions should be consulted to confirm the identification, including examination of genitalia where mature specimens are available. Where a specimen is identified as an undescribed species then the identification should be confirmed by a specialist. This key excludes *Astacopsidrilus campbellianus* from Campbell and Macquarie Islands in the subantarctic and a few undescribed species from Western Australia and Tasmania that are too poorly known to be reliably keyed at present. It also excludes two poorly described species: *Astacopsidrilus novus* Jackson 1931 from near Perth and *Tasmaniaedrilus tasmaniaensis* Goddard, 1909 from Mount Wellington in Tasmania.

1a Anterior ventral bundles with both chaetae of a pair about equal in width and form (rarely with one narrower and straighter), both with a distinct nodulus (swelling) and usually both bifid (Figure 11) ..... 2

1b Anterior ventral chaetae dissimilar, each bundle with one broader bifid chaeta with a nodulus (upper tooth may be rudimentary to almost absent) and one narrower, straighter chaeta with a simple tip and no nodulus (Figure 12) ..... 28

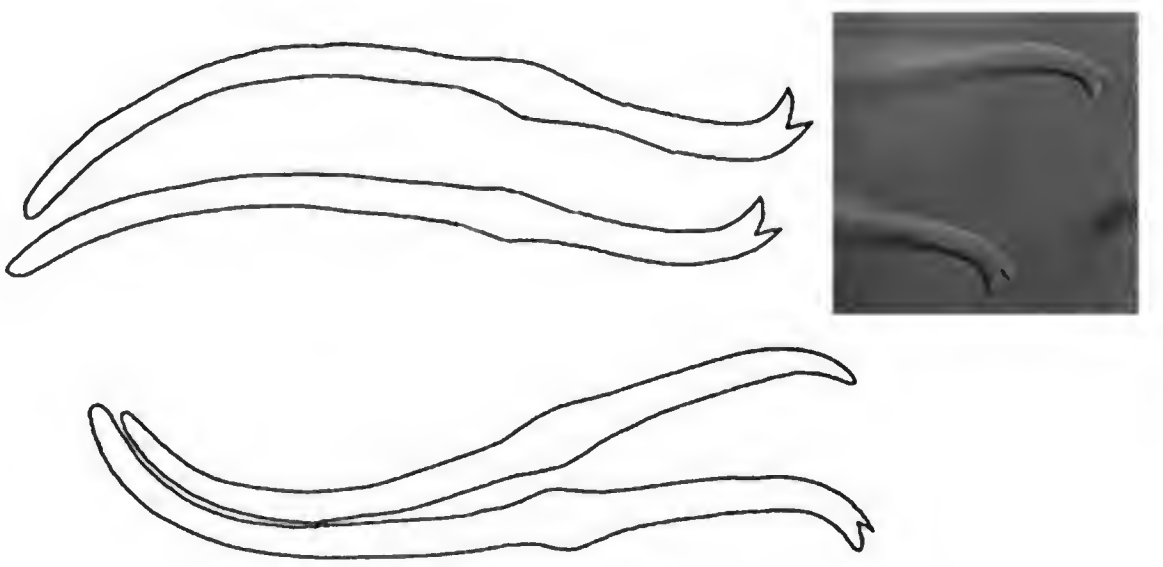

Figure 11. Ventral chaetae similar in form, usually both bifid.

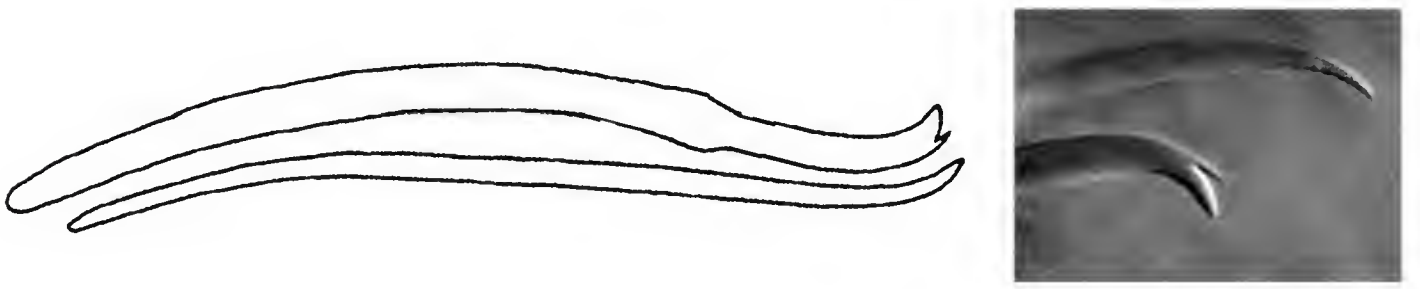

Figure12. Ventral chaetae dissimilar within a bundle.

2a All dorsal chaetae are thin hairs with fine tips and support chaetae at their base (Figure 13) ..... 10

2b At least some dorsal bundles with crotchet chaetae with bifid, single-pointed or frayed tips (Figure 14); support chaetae sometimes absent ..... 3

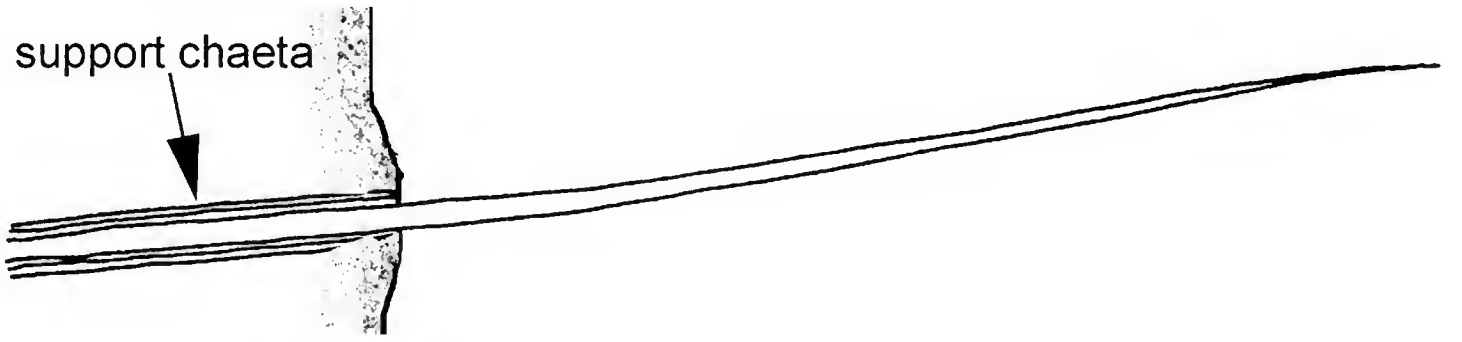


Figure13. Hair chaeta with support chaetae at base.

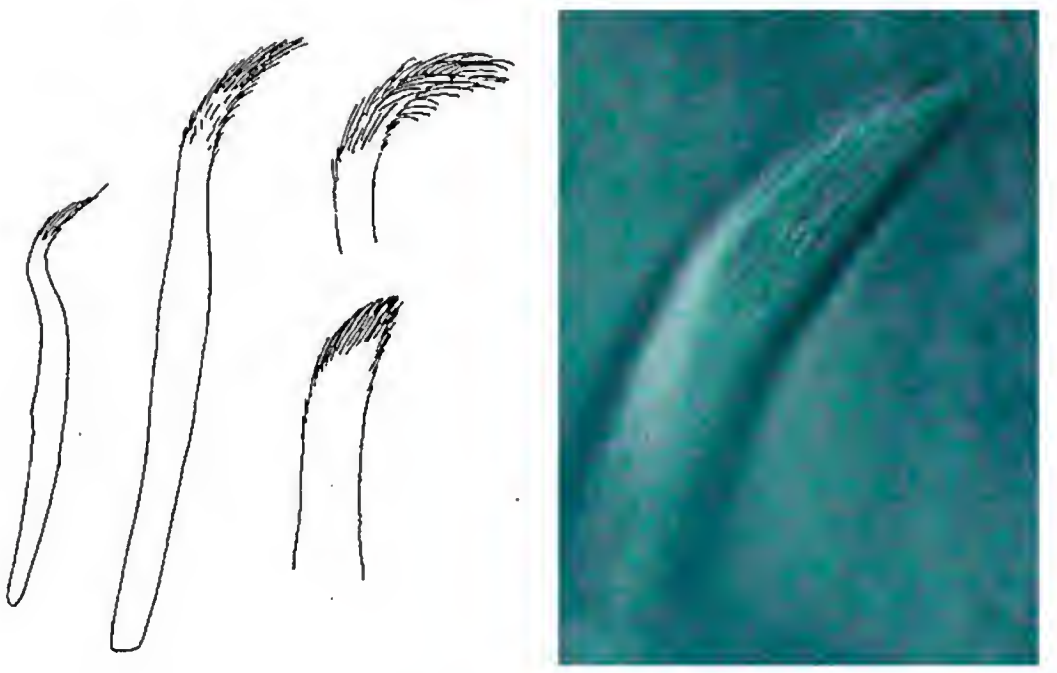

Figure 14. Plumose dorsal chaetae of *Insulodrilus magnaseta*. Drawings from Pinder and Brinkhurst (1997a) © CSIRO Publishing.

3a Dorsal chaetae in some or all segments with frayed (plumose or brush-like) tips (Figure 14) ..... 8

3b Dorsal chaetae all bifid or single-pointed crotchets without frayed ends (Figures 15 and 16) ..... 4

4a Dorsal chaetae all bifid crotchets (Figure 15), one or two per bundle; support chaetae absent; ventral chaetae clearly toothed ..... *Insulodrilus bifidus* (South-western Australia)

4b Dorsal chaetae all single-pointed ..... 5

Figure 15. Bifid dorsal chaeta of *Insulodrilus bifidus.*

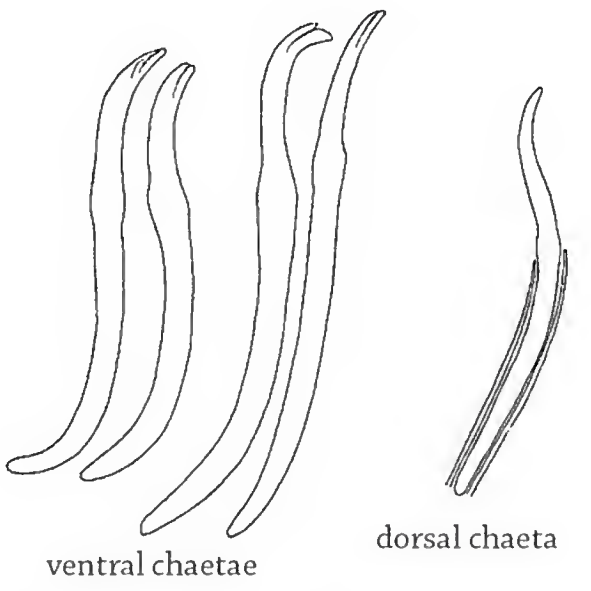


Figure 16. *Insulodrilus unisetoides*. Notched ventral chaetae and single-pointed dorsal chaeta with support chaetae. From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

5a Tips of ventral chaetae notched, giving the appearance of rounded teeth (Figure 16) .. *Insulodrilus unisetoides* (Tasmania)

5b Tips of ventral chaetae not notched ..... 6

6a Support chaetae present in dorsal bundles ..... Phreodrilidae 'WA10' (South-western Australia: Inland granite outcrops)

6b Support chaetae absent in dorsal bundles ..... 7

7a Dorsal chaetae blunt; dorsal chaetae absent in III and IV ..... *Antarctodrilus uniseta* (Tasmania)

7b Dorsal chaetae acutely pointed; dorsal chaetae present from III ..... Phreodrilidae WA25 (South-western Australia)

8a Anterior dorsal chaetae long thin hairs without frayed tips, gradually becoming stouter, more sigmoid, nodulate and with more frayed tips posteriorly (Figure 17); ventral chaetae absent on XIII; atrium <300 µm long; body wall with deep folds; commensal on crayfish ..... *Astacopsidrilus jamiesoni* (south-east Queensland)

8b All dorsal chaetae with frayed tips; ventral chaetae of XIII modified as spermathecal chaetae; atrium > 600 µm long; not known to be commensal ..... 9

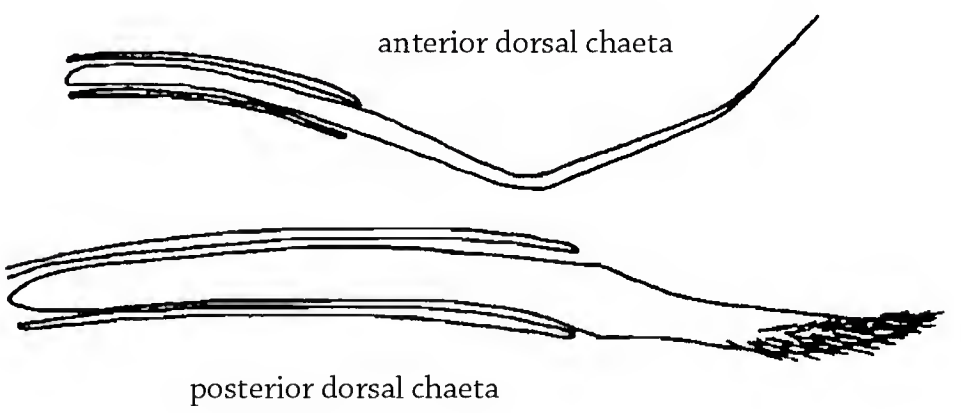


Figure17. *Astacopsidrilus jamiesoni* dorsal chaetae. From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

9a Ventral chaetae simple or with very small upper teeth, becoming much longer and stouter from II to VII then smaller again from VIII (Figure 18); dorsal chaetae becoming much stouter and blunter behind XIII ..... ..... *Insulodrilus magnaseta* (Tasmania)

9b Ventral chaetae all distinctly bifid, not changing much in size along body (Figure 19); dorsal chaetae not becoming stouter and blunter behind XIII ..... *Astacopsidrilus plumaseta* (Tasmania)

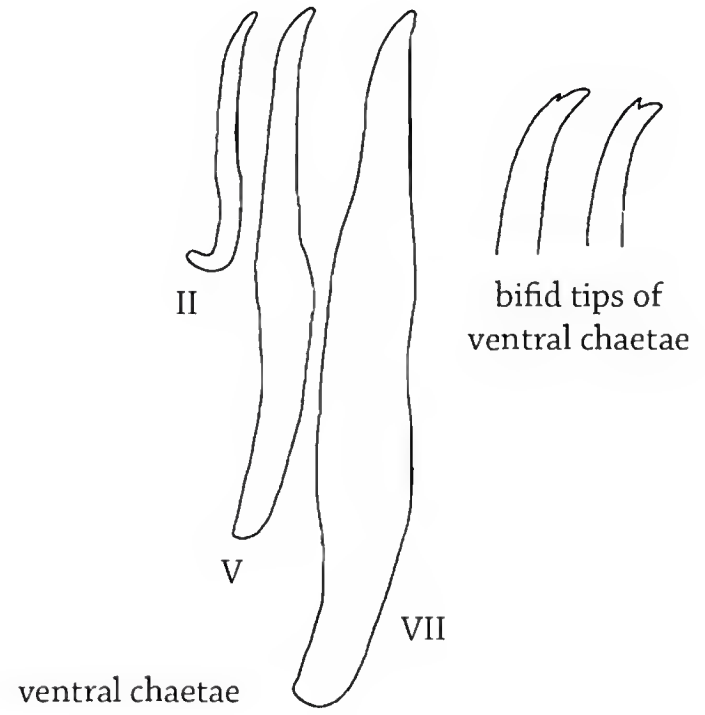


Figure 18. *Insulodrilus magnaseta* ventral chaetae. From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

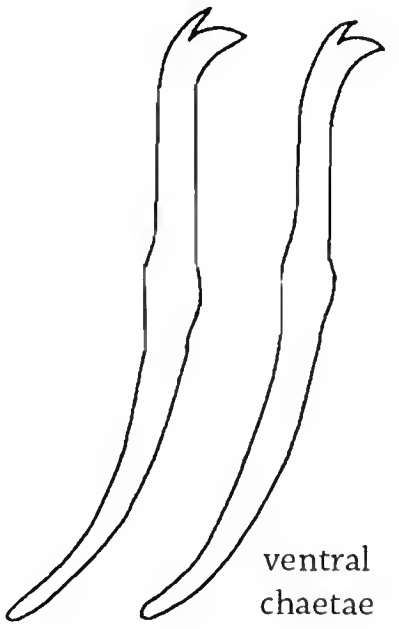


Figure 19. *Astacopsidrilus plumaseta* ventral chaetae. From Pinder and Brinkhurst (1997a) © CSIRO Publishing

10a Dorsal chaetae increasing in number to > 10 per bundle on mid-body and/or posterior segments ..... 11

10b Dorsal chaetae not increasing to such numbers ..... 13

11a One to three long (> 100 µm) hairs present in anterior bundles, changing in mid-body to shorter and thinner hairs (< 60 µm long) which increase in number to as many as 50 per bundle surrounding one long hair in the last few segments (Figure 20) ..... *Antarctodrilus* sp. 'WA3'(south-western Australia)
(Note that the tail segments often break off during preservation so the dense bundles of posterior chaetae are missing).

11b One to six long (> 200 µm) hairs per bundle present anteriorly, increasing in number medially to 10-20 per bundle, but not increasing further in number posteriorly ..... 12

12a Dorsal chaetae 3 to 6 hairs per bundle anteriorly, increasing in number to as many as 16 on mid-body segments (Figure 21); anterior segments increasing greatly in width so that the anterior appears conical in shape; spermathecal pores ventro-lateral ..... *Insulodrilus breviatria* (Known only from Great Lake and Arthurs Lake in Tasmania)

12b Dorsal chaetae 1 or 2 hairs per bundle anteriorly, increasing in size and number to as many as 19 medially, then decreasing in size and number posteriorly; anterior segments not greatly increasing in width; spermathecal pores dorso-lateral ..... ..... *Antarctodrilus palustris* (Great Lake in Tasmania)

Figure 20. Posterior dorsal chaetae of *Antarctodrilus* 'WA3'

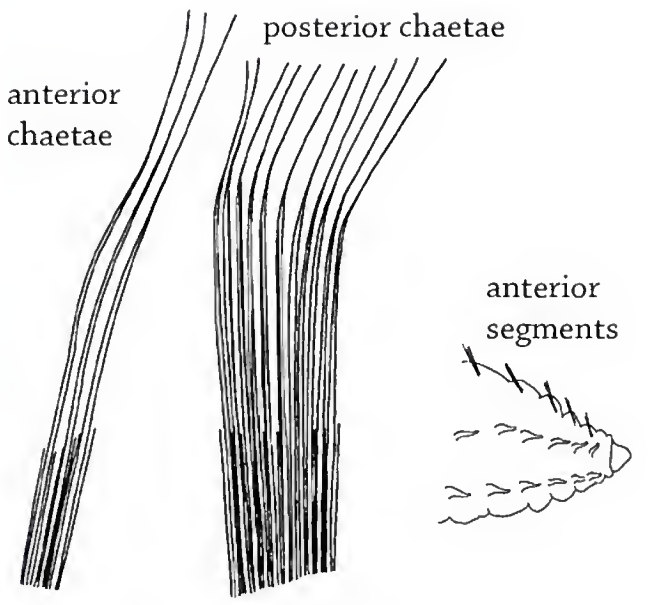


Figure 21. *Insulodrilus breviatria* dorsal chaetae. From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

13a Hair chaetae short (usually <120 µm) with fine or whip-like tips (hairs tapering abruptly in distal half to one fifth) (Figures 22 and 23) ..... 14

13b Hair chaetae usually longer and all narrowing evenly along shaft (Figure 13)..... 15

14a One (rarely two) dorsal chaetae per bundle with the non-tapering basal part protruding well out of the body wall (Figure 22) ..... *Insulodrilus nudus* (south-eastern Australia including Tasmania)
(Similar specimens from south-western Australia may be an undescribed species)

14b One to three hairs per bundle with only the tapering part protruding from the body wall (Figure 23) ..... *Insulodrilus parviseta* (Tasmania)

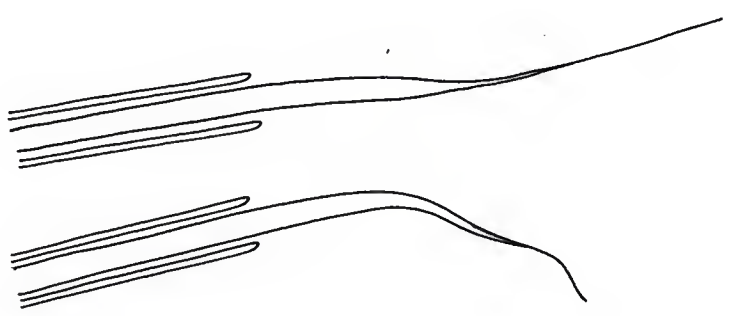

Figure 22. Dorsal chaetae of *Insulodrilus nudus*.

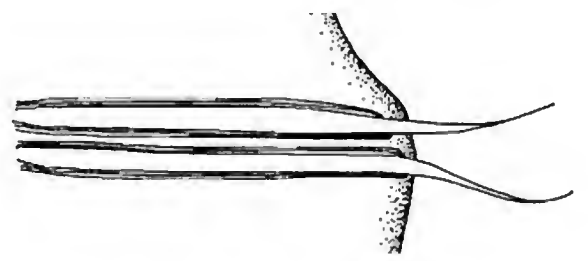

Figure 23. Dorsal chaetae of *Insulodrilus parviseta.* From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

15a Anterior ventral chaetae bifid with the upper tooth longer than the lower (rarely single-pointed), teeth becoming equal or the lower larger medially and setae all single-pointed posteriorly (Figure 24); spermathecal vestibulae extremely muscular (see Figure 157 in Pinder and Brinkhurst 1997a) ..... *Astacopsidrilus myothyros* (Tasmania)

15b All ventral chaetae single-pointed or bifid with upper teeth much smaller than lower; spermathecal vestibule not extremely muscular ..... 16

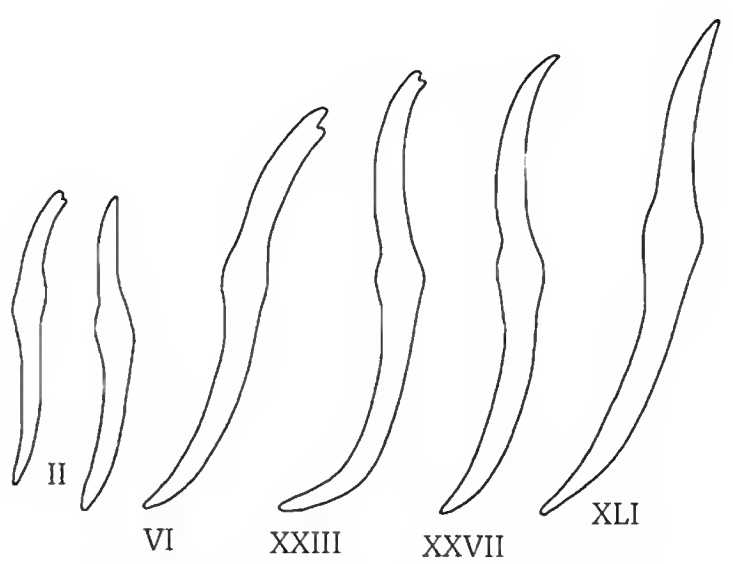


Figure 24. Ventral chaetae of *Astacopsidrilus myothyros*. From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

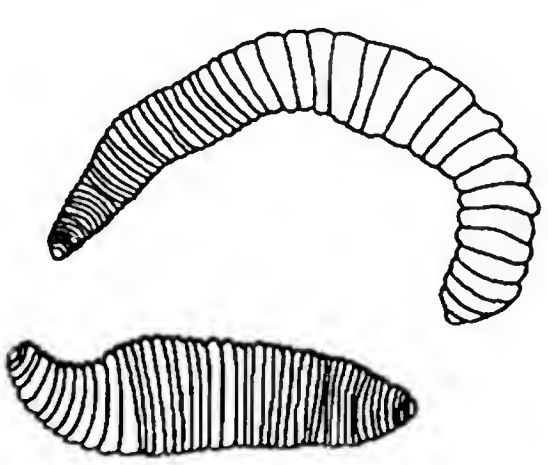

Figure 25. Body forms of *Astacopsidrilus notabilis* and *Astacopsidrilus fusiformis*. From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

16a Body leech-like, with short segments (Figure 25); commensal on crayfish .....
..... *Astacopsidrilus notabilis* and *Astacopsidrilus fusiformis* (eastern Australia)
(These two species inadequately described to distinguish)

16b Body elongate, not leech-like; not known to be commensal on crayfish ..... 17

17a Body very small (total length < 3.5 mm when preserved); ventral chaetae < 40 µm long; spermathecal pores dorso-lateral; atrium < 5 times longer than wide, with narrow lumen (Figure 26) .....
..... *Antarctodrilus micros* (South-western Australia)
(Possibly also a second similar species in Yanchep caves near Perth)

17b Body larger (usually >6 mm when preserved); ventral chaetae > 45 µm; spermathecal pores dorso-lateral or ventro-lateral; atrium > 8 times longer than wide, or if shorter then with broad lumen and usually filled with sperm..... 18

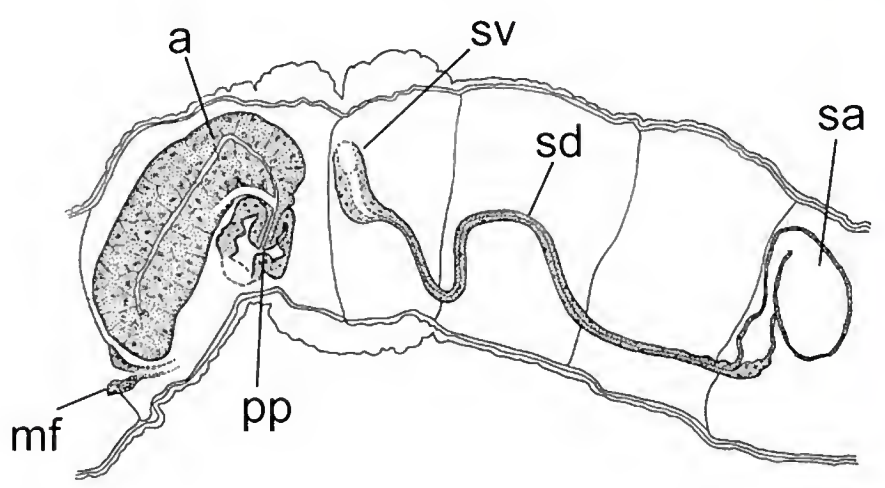


Figure 26. *Antarctodrilus micros* showing short broad atrium (a) and dorso-lateral spermathecal vestibule and pore (sv). From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

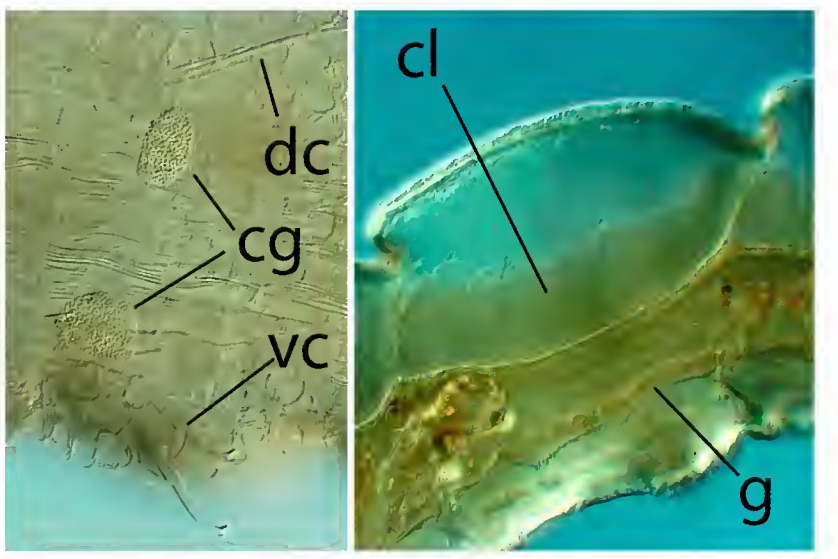


Figure 27. Phreodrilid WA16. Left: ventral (vc) and dorsal (dc) chaetae with ovoid chaetal glands (cg). Right: thick layer of tall chlorogogue cells (cl) lining gut (g).

18a Tall glandular cells surrounding gut and on either side of each septa (Figure 27, right); 'dorsal' chaetae are lateral rather than dorso-lateral and both those and the ventral chaetae are associated with distinct ovoid granular glands (Figure 27, left); ventral chaetae of anterior few segments much larger than the rest ..... Phreodrilidae WA16 (South-western Australia)

18b Without the above combination of characters ..... 19

19a Mouth and pharynx very large (Figure 28); penes not much longer than wide .....
..... Phreodrilidae WA24A (South-western Australia: under moss beds on granite outcrops – Mount Chudalup)

19b Penes much longer than wide; mouth normal size (narrow slit between prostomium and segment I – see Figure 2) and pharynx not as well developed ..... 20

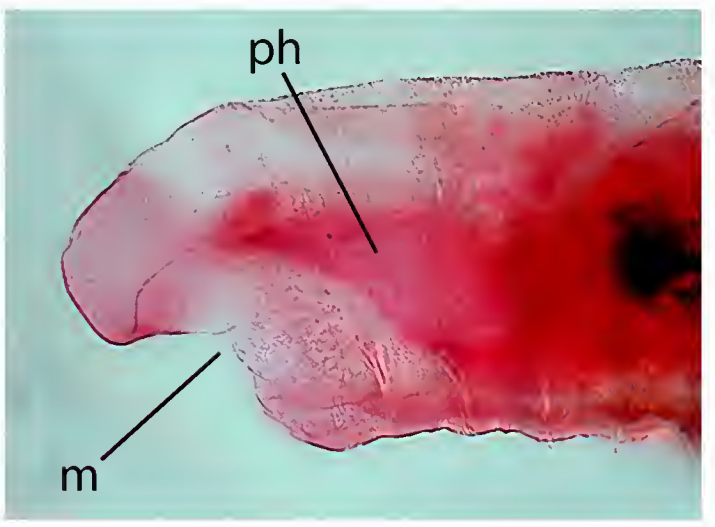


Figure 28. Wide mouth (m) and large pharynx (ph) of Phreodrilidae WA24A.

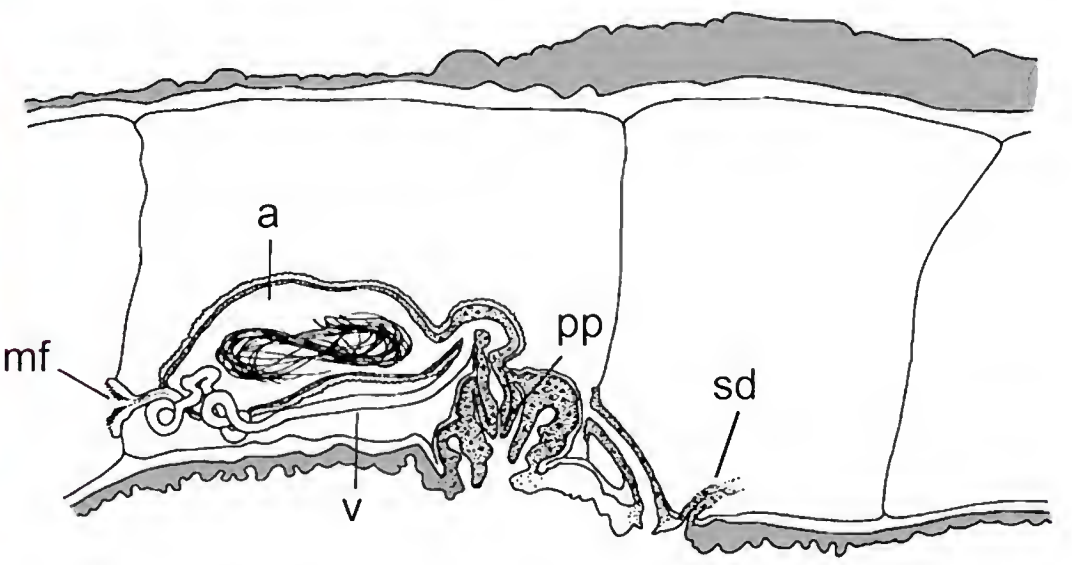


Figure 29. *Phreodriloides notabilis* genitalia showing short hollow atrium (a) containing sperm, partially developed spermathecal duct (sd) and absence of spermathecal ampullae. From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

20a Mature specimens with modified 'spermathecal' ventral chaetae on XIII (Figures 5 and 31) ..... 23

20b Mature specimens without modified chaetae on XIII ..... 21

21a Spermathecae absent (although rudiments of pores and ducts may be present); atrium short and muscular, < 4 times longer than wide, hollow and usually filled with sperm (
Figure)

*Phreodriloides notabilis* (Victoria and New South Wales, with most records in lakes and streams of the Snowy Mountains)

21b Spermathecae present; atrium not muscular, > 4 times longer than wide and with a narrow lumen ..... 22

22a Spermathecal pores dorso-lateral; eversible pseudopenes present; dorsal hair chaetae > 100 µm long .....
..... *Phreodrilus mitodes* (Figure 30) (Tasmania)

22b Spermathecal pores ventral; male pores on very small pendant penes; dorsal hairs < 100 µm long .....
..... *Nesodrilus southwellensis* (Tasmania)

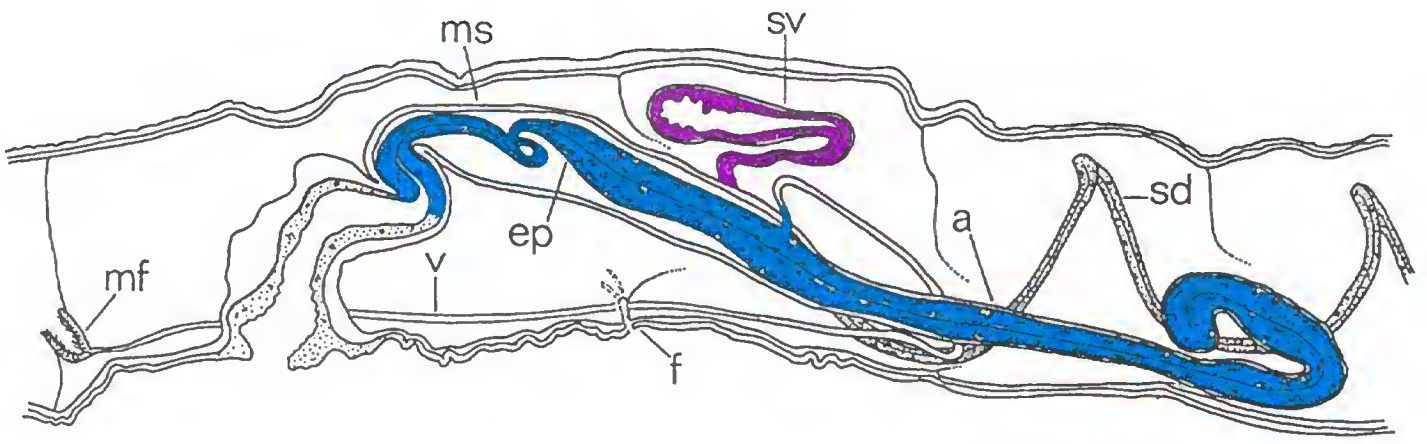


Figure 30. *Phreodrilus mitodes*, showing eversible pseudopenis (ep) and atrium (a) in blue and dorso-lateral spermathecal pore and vestibule (sv) in purple. From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

23a Spermathecal duct terminates on a small ventro-lateral papilla within a shallow invagination of body wall (Figure 31) .....
..... Phreodrilidae WA15 (South-western Australia)

23b Spermathecal pores terminate at apex of deeper invaginations (vestibulae) of the ventro-lateral body wall (e.g. Figures 33 and 34)..... 24

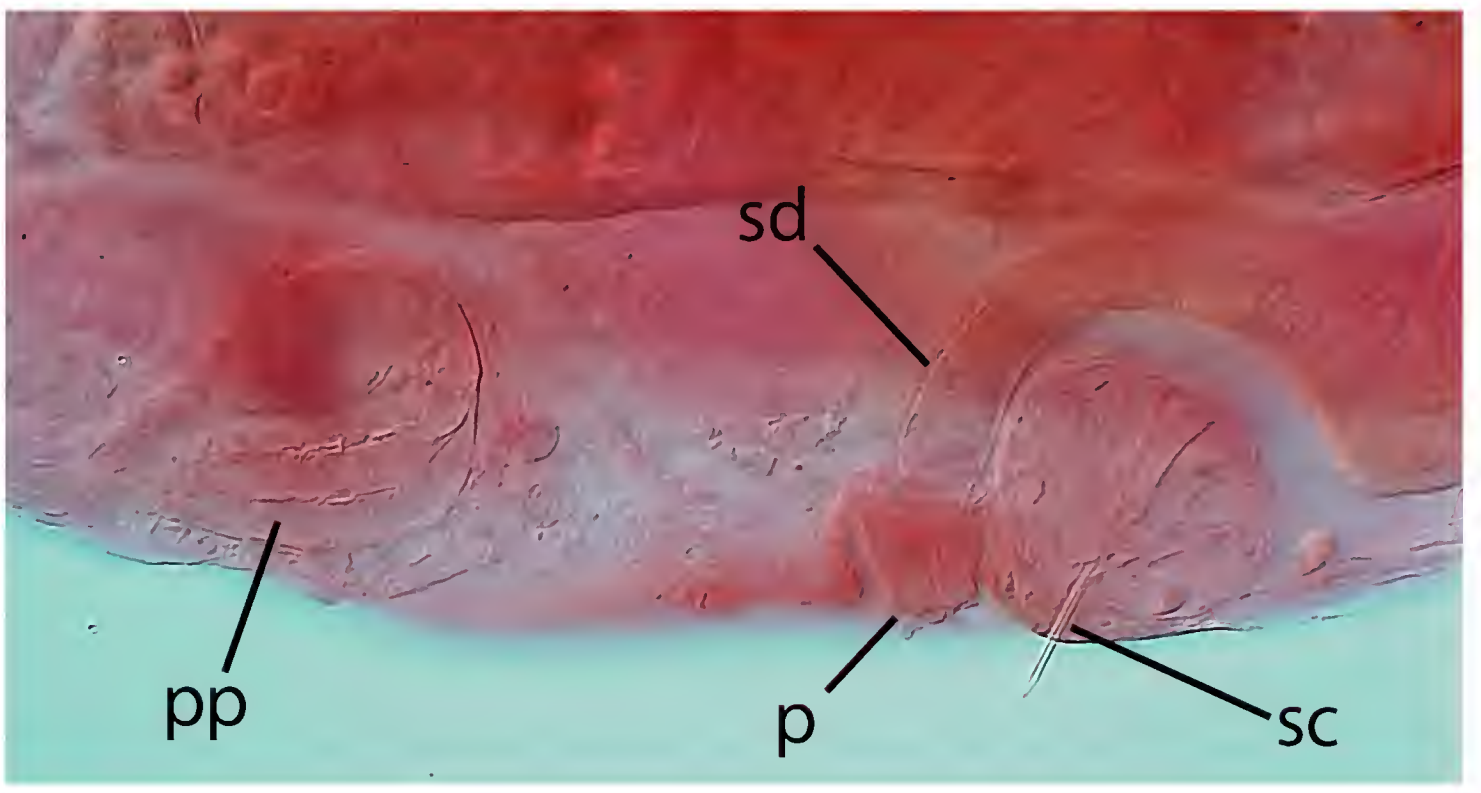


Figure 31. Genitalia of Phreodrilidae WA15 showing pendant penis (pp) with crinkly cuticular sheath, spermathecal duct (sd) terminating on papilla (p) in front of spermathecal chaeta (sc).

24a Atria very short and stout (length < 5 times width) narrowing abruptly to form distinct narrow ducts connected to apex of penes (Figure 32)..... Phreodrilidae WA21 (South-western Australia, granite outcrops in the Wheatbelt region)

24b Atria much narrower and convoluted, (*e.g.* Figures 10 bottom and 34) ..... 25


Figure 32. Phreodrilidae WA21 with short broad atrium (a) narrowing to form an ejaculatory duct (ed).


Figure 33. Phreodrilidae WA22 showing spermathecal duct (sd), terminating on a papilla (pa) protruding into the spermathecal vestibule (sv), adjacent to the modified spermathecal chaetae (sc).

25a Spermathecal vestibulae short, less than half the height of the body, with less extensive muscle connections to the body wall ..... 26

25b Spermathecal vestibulae tall, occupying more than three-quarters of the body height in XIII, with muscular attachments to the dorsal and lateral body wall (*e.g.*Figure 34) ..... 27

26a Spermathecal ducts terminate on papillae protruding into the spermathecal vestibulae (Figure 33)..... ..... Phreodrilidae WA22 (South-western Australia, known only from a granite rock near Balladonia)

26b Spermathecal ducts terminate at the apex of spermathecal vestibulae but not on papillae ..... ..... *Insulodrilus lacustris* complex (including *I. angela* in Pilbara region of WA)

(Note: Australian specimens once identified as *I. lacustris* (*e.g.* Pinder and Brinkhurst, 1997a) most likely belong to a suite of similar species rather *I. lacustris sensu strictu*. Some specimens from the Pilbara have been described as *Insulodrilus angela* Pinder, 2008, but specimens from south-western and south-eastern Australia also appear to be separate but undescribed species. *I. lacustris* was described from New Zealand but there are records from South America).

27a A swelling present on the spermathecal duct just posterior to the vestibule (arrowed on Figure 34) ..... ..... *Astacopsidrilus edwardi* (saturated moss beds and seepages on granite rocks in inland south-western Australia)

27b No swelling present on spermathecal duct ..... ..... undescribed *Astacopsidrilus* (*e.g.* some known from groundwater and caves in Western Australia)

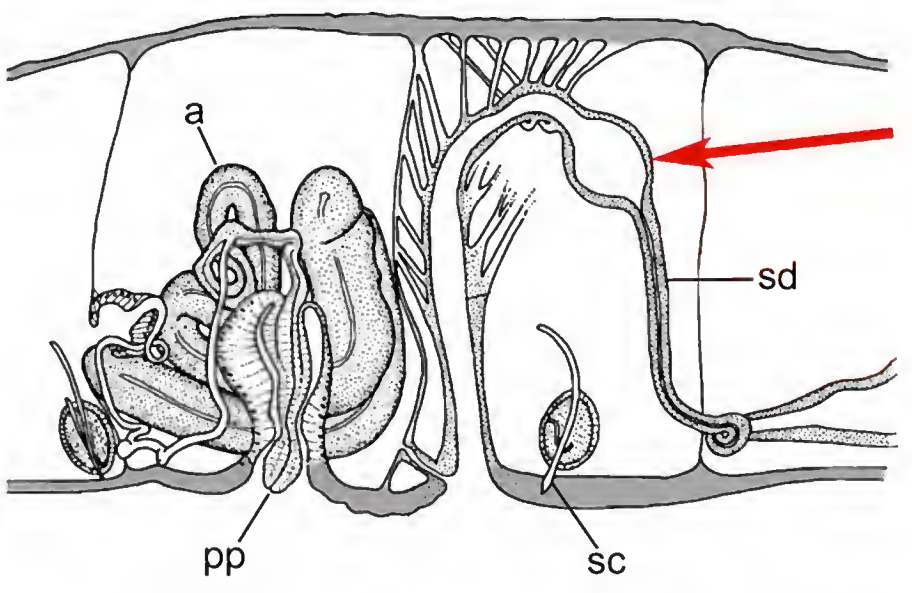


Figure 34. *Astacopsidrilus edwardi* showing swelling (arrowed) on tall muscular spermathecal duct (sd) and pendant penis (pp) less than half body height. From Pinder (2003) © Western Australian Museum

Figure 35. Gills on posterior segments of *Phreodrilus branchiatus*.

28a Paired dorso-lateral gills present on posterior segments (Figure 35).....

..... *Phreodrilus branchiatus* (Victoria, New South Wales and Tasmania)
(Beware specimens with tail end missing).

28b Gills absent ..... 29

29a Proboscis present on prostomium; dorsal bundles with annulated hairs, at least anteriorly (Figure 36)..... 30
29b Proboscis absent; dorsal hairs annulated or smooth or hairs absent ..... 31

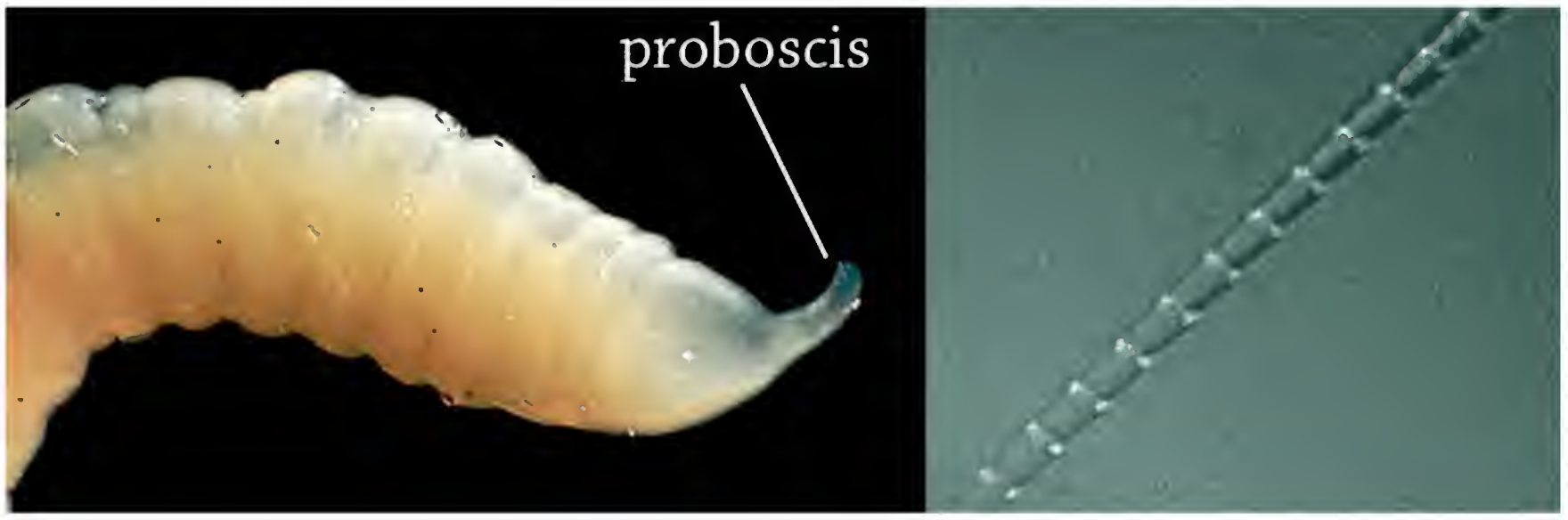


Figure 36. Proboscis (left) and annulated hair (right) of *Antarctodrilus proboscidea*.

30a Dorsal hair chaetae all long and thin, 1-4 per bundle .....
..... *Antarctodrilus proboscidea* (Victoria, New South Wales and Tasmania)
30b Dorsal hair chaetae long and thin anteriorly, 2-4 per bundle, shorter and more blade-like posteriorly and 4-6 per bundle
(Figure 37)..... *Antarctodrilus acanthaseta* (Tasmania)

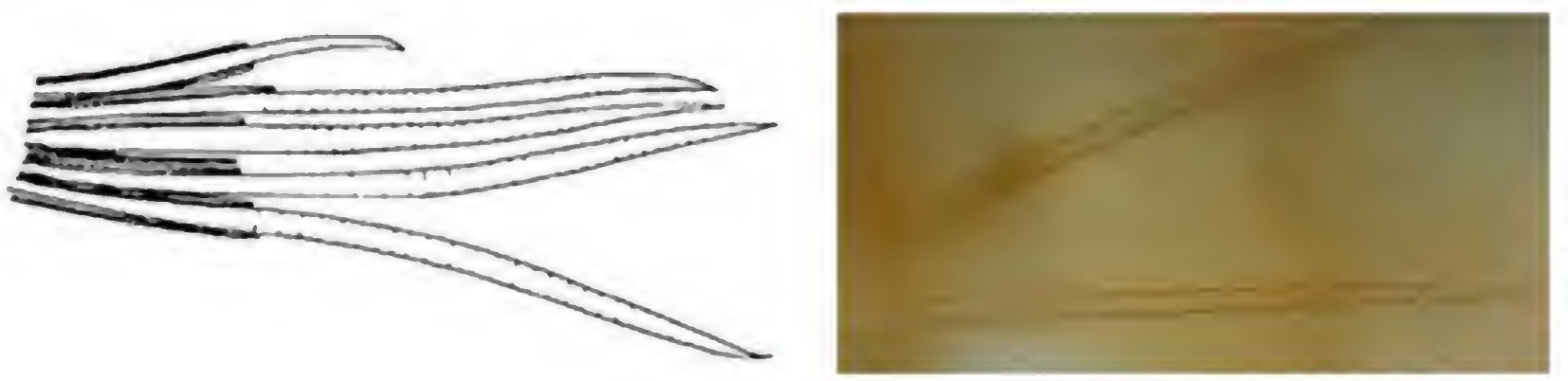

Figure 37. Posterior dorsal chaetae of *Antarctodrilus acanthaseta*. Drawing from Pinder and Brinkhurst (1997a) © CSIRO Publishing.

31a Dorsal bundles with annulated hairs (Figure 36, right)..... Phreodrilid WA6 (South-western Australia)
31b Hairs smooth ..... 32

32a Ventral chaetae on XIII modified, each bundle with one chaeta with a thin hollow tip and one with a leaf-shaped tip
(Figure 38)..... Phreodrilid TAS1 (Tasmania)
32b Ventral chaetae on XIII absent or not modified ..... 33

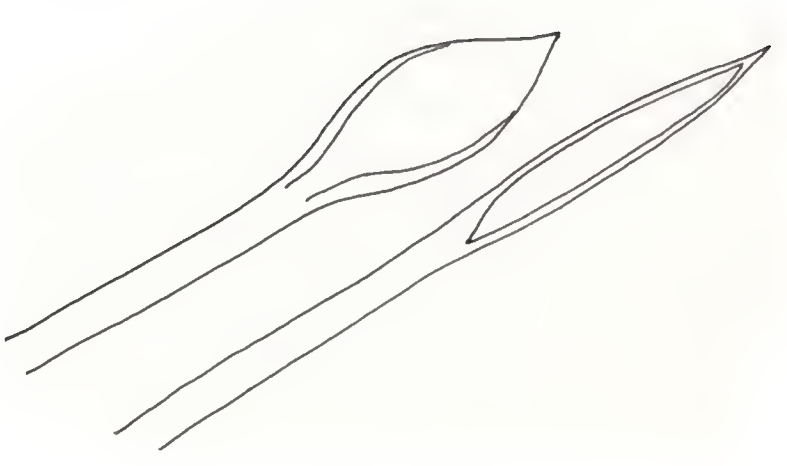

Figure 38. Spermathecal chaetae of Phreodrilid TAS1.

33a Eversible pseudopenes present (see explanation above), with or without a small pendant penis at the apex of an invagination of the body wall (*e.g.* Figure 41) ..... 35

33b Eversible pseudopenes absent, male ducts terminate in a pendant penis occupying the whole penis sac ..... 34

34a Two to four hair chaetae in most dorsal bundles; atrial lumen broad, at least at the inner extent (Figure 39), and often containing sperm ..... *Antarctodrilus horwitzi* (South-western Australian surface water and very similar looking specimens in groundwater in mid-west WA)

34b One hair chaeta per dorsal bundle, atrial lumen narrow throughout ..... *Antarctodrilus niger* (Tasmania)
(Note: Originally described from the Falkland Islands as *Hesperodrilus niger*, other specimens called *A. niger* (partly through synonymy) are from South Africa and Tierra de Fuego. Specimens from southern Tasmania were identified as *A. niger* by Brinkhurst (1982), but there is probably a complex of species involved.)

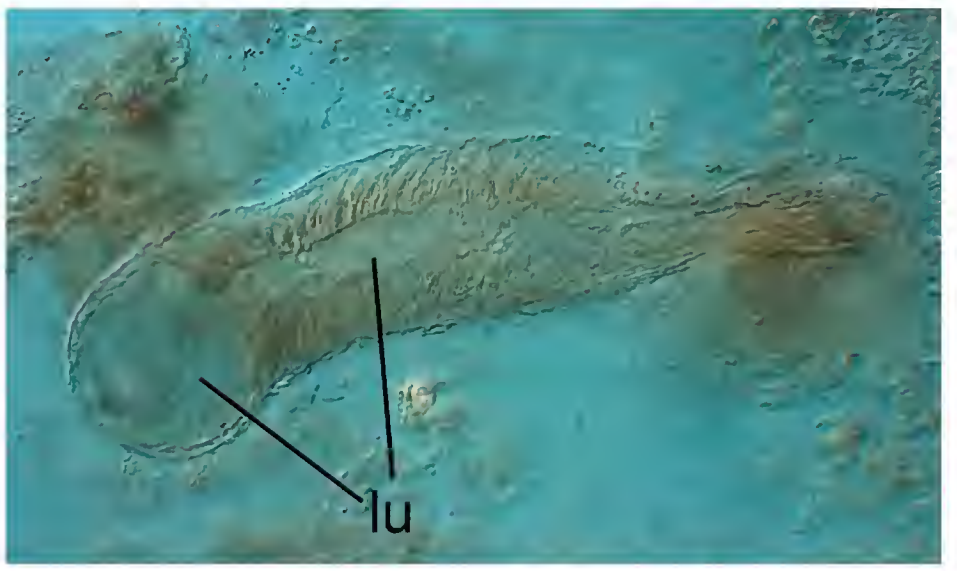


Figure 39. Atrium of *Antarctodrilus horwitzi* with broad atrial lumen (lu).

35a Pseudopenes not coiled when retracted (or only very weakly so) (Figures 40 and 41) ..... 36

35b Pseudopenes strongly coiled when retracted (Figures 42 and 43) ..... 37

36a Atrium elongate (> 1000 µm long and < 50 µm wide) (Figure 40); when retracted male duct terminates simply at apex of a long sac formed by invagination of body wall ..... *Phreodrilus melaleucensis* (Tasmania)

36b Atrium not so elongate (< 500 µm long and up to 120 µm wide); when retracted male duct terminates on a small papilla at the apex of an invagination of body wall (Figure 41) ..... ..... *Phreodrilus peniculus* (springs and groundwater in Pilbara region of Western Australia).
(Has also been called Phreodrilidae WA12).

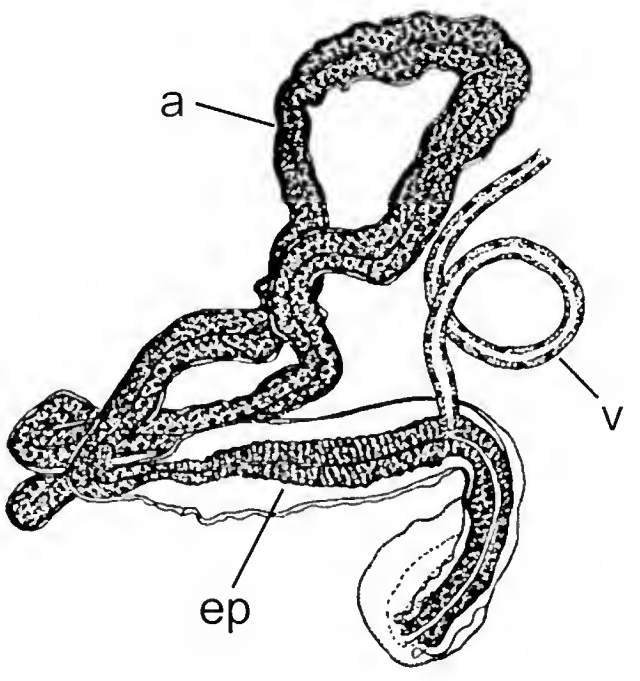


Figure 40. Vas deferens (v), atrium (a) and eversible pseudopenis (ep) of *Phreodrilus melaleucensis*. From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

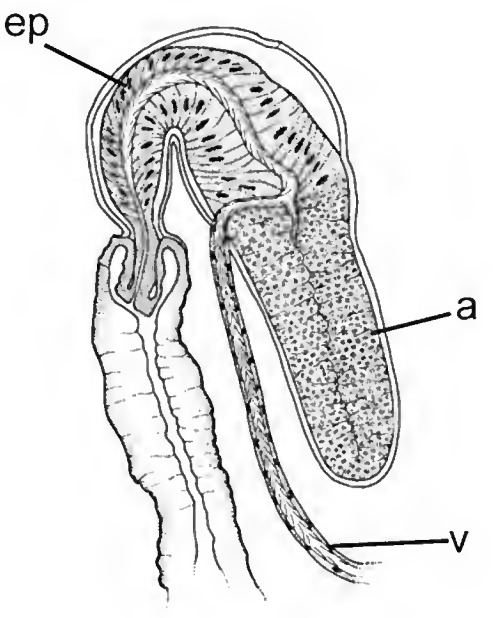


Figure 41. *Phreodrilus peniculus*, showing eversible pseudopenis (ep) terminating in a small papilla at the apex of an invagination of the body wall. From Pinder (2003) © Western Australian Museum.

37a Atrium small (< 150 µm), length less than twice the width; when retracted the eversible pseudopenis terminates at a papilla at the inner end of an invagination in the body wall (Figure 42); spermathecal duct complex, with broader medial section with larger cells, then narrowing before joining ampulla ..... .....*Phreodrilus linnae* (Groundwater in Pilbara region of Western Australia)

37b Atrium longer (> 200 µm), length 4 to 5 times the width (Figure 43); when retracted the eversible pseudopenis terminates at the apex of an invagination in the body wall (but not on a papilla); spermathecal duct relatively uniform in width and histology ..... *Phreodrilus diemenensis* (Known only from Tasmania)

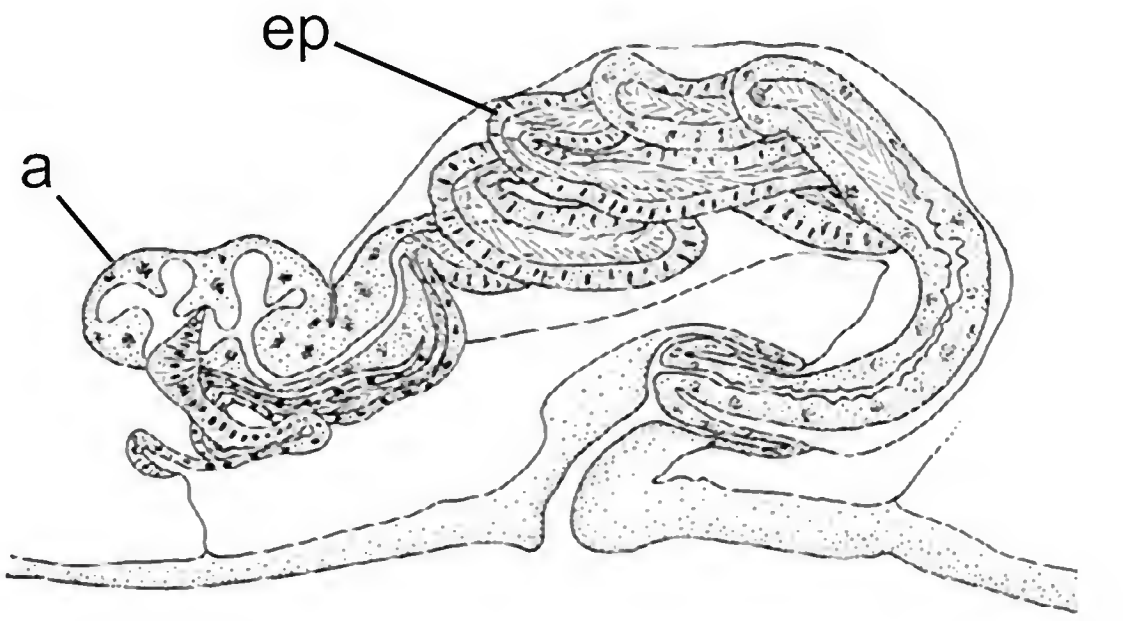


Figure 42. Male ducts of *Phreodrilus linnae* with strongly coiled eversible pseudopenis (ep) and short atrium (a). From Pinder (2008) © Western Australian Museum.

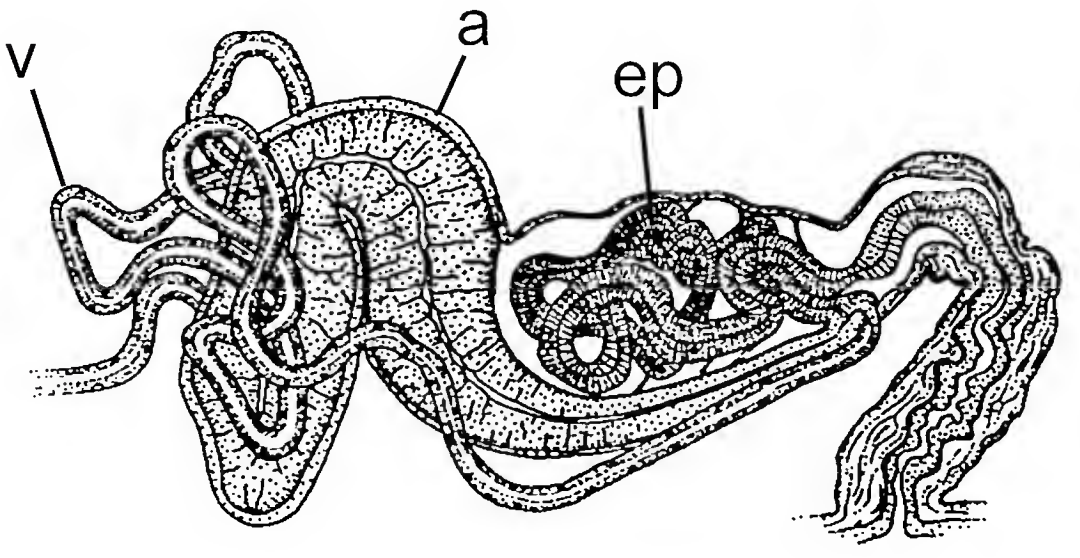


Figure 43. *Phreodrilus diemenensis* showing longer atrium (a) (compared to *P. linnae*) and strongly coiled pseudopenis (ep) leading to an invagination of the body wall without a papilla. From Pinder and Brinkhurst (1997a) © CSIRO Publishing.

## Key to Australian Capilloventridae

1a Chaetae absent in II and III, present from IV onwards, each bundle from IV with a short hair and a bifid crotchet chaeta, with the length of the hair chaetae decreasing posteriorly (Figure 44) ..... ..... *Capilloventer australis* (freshwater to estuarine, South-eastern Victoria and eastern New South Wales)

1b Chaetae absent in II, present from III onwards; anterior segments only with hair chaetae ..... 2

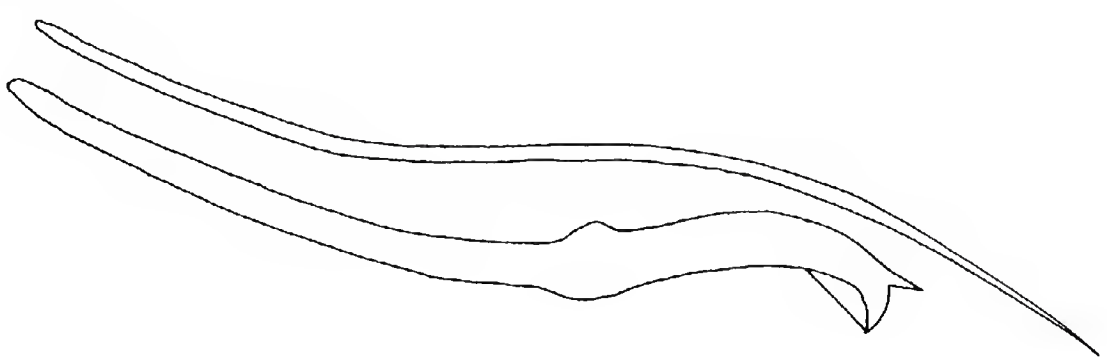

Figure 44. Hair and bifid chaeta from posterior segments of *Capilloventer australis*. From Pinder and Brinkhurst (1997b) © John Wiley & Sons Ltd.

2a Prostomium elongate (Figure 45) posterior chaetae all bifid..... *Capilloventer longicapitus* (Victoria)

2b Prostomium rounded (Figure 46) posterior chaetal bundles each with one crotchet bifid and one sharply single-pointed ... ..... *Capilloventer acheronensis* (Victoria)

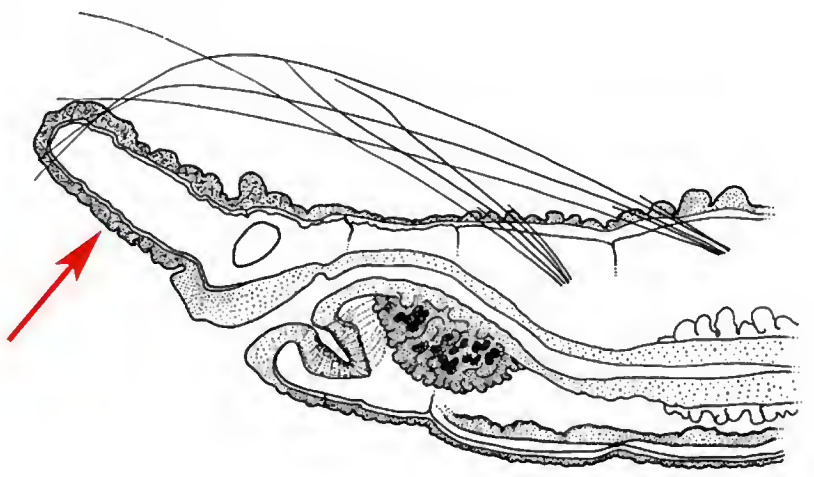

Figure 45. Anterior of *Capilloventer longicapitus* with long prostomium indicated by arrow. From Pinder and Brinkhurst (1997b) © John Wiley & Sons Ltd.

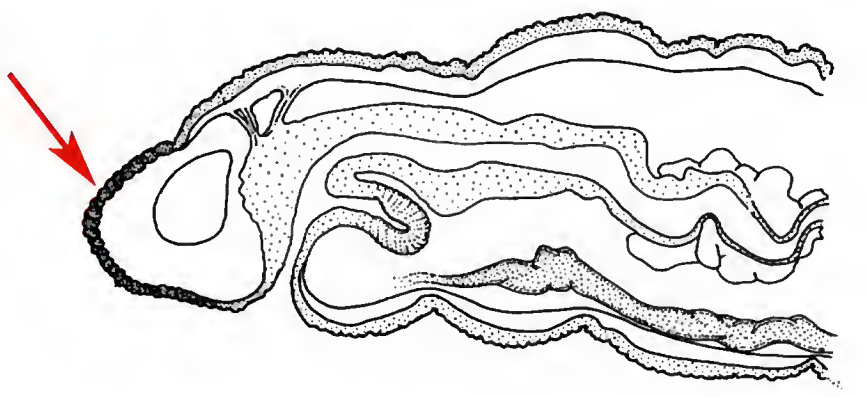

Figure 46. Anterior of *Capilloventer acheronensis* with rounded prostomium indicated by arrow. From Pinder and Brinkhurst (1997b) © John Wiley & Sons Ltd.

## Key to Australian Lumbriculidae

1a Live specimens with anterior segments dark and posterior segments lighter reddish (Figure 47); posterior segments each with a pair of branched blood vessels (easily seen on live or slide mounted specimens) ..... *Lumbriculus variegatus* s.l. (Cosmopolitan, widespread in southern Australia but mostly in catchments of urbanized or agricultural areas, almost certainly a recent introduction)

1b Without the above combination of characters ..... 2

Figure 47. Photo of live *Lumbriculus variegatus.*

2a Mature specimens with non-retractable penes on segment X (Figure 48) ..... *Stylodrilus heringianus* (Palaearctic, in Australia known only from one record in Tasmania. Also from New Zealand, almost certainly a recent introduction)

2b Immature specimens or mature specimens without non-retractable penes ..... either immature *S. heringianus* or a species not previously recorded from Australia

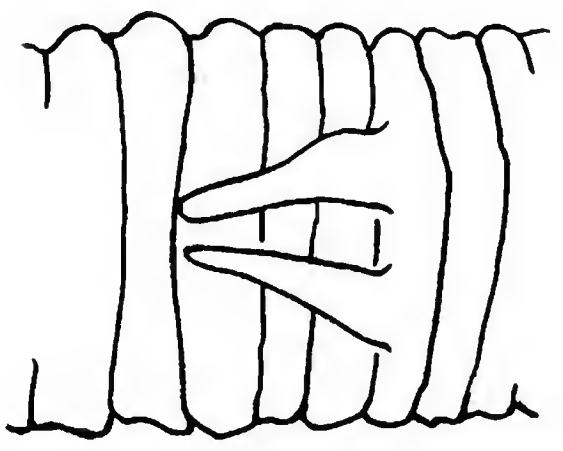

Figure 48. Penes of *Stylodrilus heringianus*. Redrawn from Marshall, 1978.

## Checklist of Australian Phreodrilidae

Described phreodrilids known from Australia are listed below. In addition to these, there are 16 undescribed species known from Western Australia and at least one undescribed species from Tasmania.

| ***Species*** | **Authority** | **Distribution** |
|---|---|---|
| *Antarctodrilus acanthaseta* | Pinder and Brinkhurst, 1997 | Tas |
| *Antarctodrilus horwitzi* | Pinder and Brinkhurst, 1997 | **swWA** |
| *Antarctodrilus micros* | Pinder and Brinkhurst, 1997 | swWA |
| *Antarctodrilus niger* | (Beddard, 1894) | Tas, Falkland Islands, South America |
| *Antarctodrilus palustris* | (Brinkhurst and Fulton, 1979) | Tas |
| *Antarctodrilus proboscidea* | (Brinkhurst and Fulton, 1979) | Tas, Vic, NSW |
| *Antarctodrilus uniseta* | (Brinkhurst, 1982) | Tas |
| *Astacopsidrilus campbellianus* | (Benham, 1909) | Macquarie Island, Campbell Island (NZ) |
| *Astacopsidrilus edwardi* | Pinder, 2003 | swWA |
| *Astacopsidrilus fusiformis* | Goddard, 1909 | NSW |
| *Astacopsidrilus jamiesoni* | Brinkhurst, 1991 | Qld |
| *Astacopsidrilus myothyros* | Pinder and Brinkhurst, 1997 | Tas |
| *Astacopsidrilus notabilis* | Goddard, 1909 | NSW |
| *Astacopsidrilus novus* sp. inq. | Jackson, 1931 | swWA |
| *Astacopsidrilus ostiensis* | Pinder and Erséus, 2000 | Tas |
| *Astacopsidrilus plumaseta* | (Brinkhurst and Fulton, 1979) | Tas |
| *Insulodrilus angela* | Pinder, 2008 | nwWA |
| *Insulodrilus bifidus* | Pinder and Brinkhurst, 1997 | swWA |
| *Insulodrilus breviatria* | (Brinkhurst and Fulton, 1979) | Tas |
| *Insulodrilus* cf. *lacustris* s.l. (multiple spp.) | | Tas, Vic, swWA, nwWA |
| *Insulodrilus magnaseta* | (Brinkhurst and Fulton, 1979) | Tas |
| *Insulodrilus nudus* | (Brinkhurst and Fulton, 1979) | Tas, Vic, swWA |
| *Insulodrilus parviseta* | Pinder and Brinkhurst, 1997 | Tas |
| *Insulodrilus unisetoides* | Pinder and Brinkhurst, 1997 | Tas |
| *Nesodrilus southwellensis* | Pinder and Brinkhurst, 1997 | Tas |
| *Phreodriloides notabilis* | Benham, 1907 | Vic, NSW |
| *Phreodrilus branchiatus* | (Beddard, 1894) | Tas, Vic, South America |
| *Phreodrilus diemenensis* | Pinder and Brinkhurst, 1997 | Tas |
| *Phreodrilus linnae* | Pinder, 2008 | nwWA |
| *Phreodrilus melaleucensis* | Pinder and Brinkhurst, 1997 | Tas |
| *Phreodrilus mitodes* | Pinder and Brinkhurst, 1997 | Tas |
| *Phreodrilus peniculus* | Pinder, 2003 | nwWA |
| *Tasmaniaedrilus tasmaniaensis* sp. inq. | Goddard, 1909 | Tas |

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